Chapter A11: Habitat-Based Replacement Cost Method

Introduction

This chapter provides an overview of the habitat-based replacement cost (HRC) method for valuing losses of aquatic resources that result from I&E of organisms by a CWIS. The HRC method can be used to value a broad range of ecological and human service losses associated with I&E of aquatic species at facilities regulated under Section 316(b) of the Federal Water Pollution Control Act (Clean Water Act) [33 U.S.C. § 1251 *et seq.*]. It can be used as an alternative to conventional valuation approaches that are based on recreational and commercial fishing impacts. In addition, HRC can supplement conventional valuation results by providing a full valuation of species with I&E losses that are not fished (e.g., forage species).

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A11-1 Overview of HRC Valuation of I&E Resource Losses

A11-1.1 The Need for an Alternative to Conventional I&E Valuation Techniques

Conventional techniques to value the benefits of technologies that reduce I&E losses at § 316(b) facilities can omit important ecological and public services. For example, valuations based on expected recreational and commercial fishing impacts rely on indirectly derived nonmarket value estimates (e.g., consumer surplus per angling outing as estimated by travel cost models) and direct market values, respectively. In both instances, all benefits are based solely on direct use values of the impacted fish, and the physical impacts are characterized by the adult life stage of the species targeted by the recreational and commercial anglers. However, many I&E losses at many § 316(b) facilities are eggs and larvae, which are vital to a well-functioning ecological system but have no obvious direct use values in and of themselves. These facilities may have relatively small numbers of species and individuals that are targeted by anglers, so commercial and recreational losses may constitute only a small subset of the species lost to I&E. Even when losses of early life stages are included by conversion to adult equivalents, the ecological services and associated public values provided by early life stages that don't make it to adulthood in the environment are omitted.

Another conventional valuation technique bases the value of I&E impacts on the costs of restoring aquatic organisms using hatchery and stocking programs. However, the cost of restoring fish through stocking does not address several ecological services, and addresses others inefficiently. Moreover, biologists question whether stocked fish are equivalent to wild species, and have expressed concerned about ecological problems that have resulted from existing stocking programs (Meffe, 1992; White et al., 1997). Shortcomings associated with the use of hatchery and stocking costs to estimate the value of I&E losses include the following:

- Reliable stocking costs are available only for the few species targeted by existing hatcheries, and these tend to be the same species addressed by recreational and commercial fishing valuations.
- The reported costs often do not include transportation costs (see Chapter A9).

- The costs associated with hatchery and stocking programs do not include the value of many ecological services affected by I&E losses, because hatchery fish are released at different life stages, in different numbers, and in different places than they would be produced in the natural environment.
- Hatcheries usually produce naive fish, which do not function as well as wild fish in the environment.
- Hatchery fish lack genetic diversity and disease resistance compared to fish produced in the natural environment.
- Hatchery and stocking programs must continue as long as I&E losses occur, whereas natural habitat produces fish indefinitely once properly restored and protected.
- At a number of locations where fish stocking programs are in place, significant questions remain about whether the programs actually supplement the native fish populations, and if they do, the extent to which this occurs
- Hatchery fish can introduce diseased organisms and parasites to native populations.

A11-1.2 HRC Coverage of a Broader Range of Services and Values

The HRC method can be used in benefit-cost analyses to value a broad range of ecological and human services associated with I&E losses that are either undervalued or ignored by conventional valuation approaches. Economists and policy makers widely acknowledge that the public values environmental benefits well beyond beneficial impacts on direct uses (Boyd et al., 2001; Fischman, 2001; Fisher and Raucher, 1984; Heal et al., 2001; Herman et al., 2001; Ruhl and Gregg, 2001; Salzman et al., 2001; Wainger et al., 2001). While much of the professional literature, especially empirical investigations, focuses on recreational and other direct use values, most Americans value water resource protection and enhancement, including reduction of I&E losses, for reasons that go well beyond their desire for recreational anglers to enjoy a larger consumer surplus (or commercial anglers to enjoy greater producer surplus). Furthermore, many studies have documented public values (including passive values) from ecological services provided by a variety of natural resources sustaining (potential) environmental impacts, including: fish and wildlife (Stevens et al., 1991; Loomis et al., 2000); wetlands (Woodward and Wui, 2001); wilderness (Walsh et al., 1984); critical habitat for threatened & endangered species (Hagen et al., 1992; Loomis and Ekstrand, 1997; Whitehead and Blomquist, 1991); overuse of groundwater (Feinerman and Knapp, 1983); hurricane impacts on wetlands (Farber, 1987); global climate change on forests (Layton and Brown, 1998); bacterial impacts on coastal ponds (Kaoru, 1993); oil impacts on surface water (Cohen, 1986); and toxic substance impacts on wetlands (Hanemann et al., 1991), shoreline quality (Grigalunas et al., 1988), and beaches, shorebirds, and marine mammals (Rowe et al., 1992). In fact, a recent study (Costanza et al., 1997) estimated that Worldwide ecosystem services have a value of $16-54 trillion, a range that exceeded the Global Product of $18 trillion.

For direct use benefits such as recreational angling, the predicted change in the stock of a recreational fishery affects recreational participation levels and the value of an angling day (see also Chapter A3). However, I&E losses affect the aquatic ecosystem and public use and enjoyment in many ways not addressed by typical recreational valuation methods, creating a gap between known disruption of ecological services and what economists usually translate into monetary values or anthropocentric motives. Examples of ecological and public services (Peterson and Lubchenco, 1997; Postel and Carpenter, 1997; Holmlund and Hammer, 1999; Strange et al., 1999) disrupted by I&E, but not addressed by conventional valuation methods, include:

- decreased numbers of ecological keystone, rare, or sensitive species;
- decreased numbers of popular species that are not fished, perhaps because the fishery is closed;
- decreased numbers of special status (e.g., threatened or endangered) species;
- increased numbers of exotic or disruptive species that compete well in the absence of species lost to I&E;
- disruption of ecological niches and ecological strategies used by aquatic species;
- disruption of organic carbon and nutrient transfer through the food web;
- disruption of energy transfer through the food web;
- decreased local biodiversity;
- disruption of predator-prey relationships (e.g., Summers, 1989);
- disruption of age class structures of species;
- disruption of natural succession processes;
- disruption of public uses other than fishing, such as diving, boating, and birding; and
- disruption of public satisfaction with a healthy ecosystem.

The HRC method differs fundamentally from the commercial and recreational impact valuation method because the latter accounts for only those species and life stages that can be valued directly, such as those species targeted by recreational or commercial anglers. In contrast, the HRC method defines the value of all I&E losses in terms of the expenditures that would be required to replace all organisms lost to I&E at a CWIS through enhanced natural production in the environment. In short, the HRC method values lost resources by the costs of the programs required to naturally replace those same resources. The replaced organisms would then be available not only for commercial and recreational human use but also as prey for a wide range of aquatic and terrestrial organisms, as well as the full range of complex ecological functions provided by those organisms. As a result, the HRC method, by focusing on replacement of natural habitats, values fish and other organisms that are truly equivalent to those lost by allowing species to reproduce in their natural habitats using their native strategies. In addition, the HRC results are based on the natural replacement of all relevant species, life stages, behaviors, and ecological interactions, for as long as the habitats remain viable, and so the resulting valuations of I&E losses effectively incorporate the complete range of ecological and human services, even when those services are difficult to measure or poorly understood.

A11-1.3 How the HRC Method Works

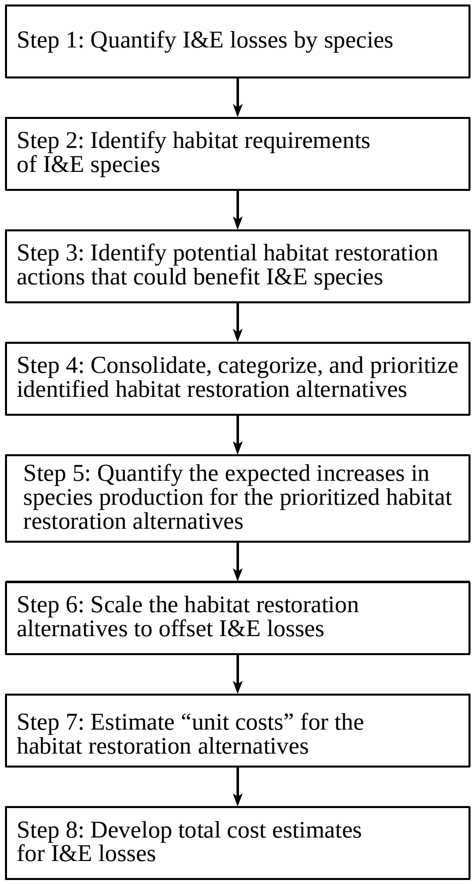
The HRC method values natural resource losses based on the costs of ecological habitat-based restoration activities, as opposed to approaches not based on habitat such as fish stocking, that are scaled to increase natural production as an offset to the I&E losses. Thus, HRC uses resource replacement costs as a proxy for the value of resources lost to I&E. Where restoration costs are very high, or where public values might be much lower than costs, economic studies can be conducted to determine the value of habitat replacements[1]. Few comparisons of restoration costs and restoration value have been made. However, the Green Bay Natural Resource Damage Assessment (U.S. Fish and Wildlife Service and Stratus Consulting, 2000) estimated both the cost and the value of habitat (and other) restorations. Public values were determined using stated preference surveys and conjoint analyses (Breffle and Rowe, 2002). Restoration costs (to offset PCB-caused injuries to the environment) totaled $111-268 million, whereas willingness-to-pay for elimination of the same PCB injuries was $254-610 million. Thus, restoration costs were considerably less than public values.

In addition to addressing a wider range of I&E losses in terms of life stages and species, the HRC method also provides regulators with information needed to evaluate proposals from the regulated party to voluntarily provide relief for expected future I&E losses associated with various permitted technologies. This information consists of a prioritized set of restoration alternatives for each species affected by I&E, estimates of the potential benefits of implementing those alternatives, and estimates of the effective unit costs for those alternatives. Figure A11-1 presents the steps required to implement an HRC valuation of I&E losses (see Parts H and I of the Case Study Document for examples of a streamlined HRC valuation).

The HRC method is a new approach for valuing losses of aquatic organisms from a CWIS, and is consistent with and related to lost resource valuation techniques such as habitat equivalency analysis (HEA) that federal courts have recognized as appropriate for use in valuing lost resources (for examples, see U.S. District Court, 1997, and U.S. District Court, 1999). Further, the principle of offsetting resource and ecosystem losses through restoration actions is incorporated in other components of the Clean Water Act, such as those addressing the losses of wetland areas (i.e., Section 404). The following subsections discuss the steps for conducting an HRC valuation of I&E losses.

[1] Although controversial, the contingent valuation method and other related techniques, such as conjoint analyses, include ecological services and passive values and have been upheld in federal court [State of Ohio v. U.S. Department of the Interior (U.S. Circuit Court, 1989)] and supported by a NOAA panel co-chaired by 2 Nobel Laureate economists (Arrow et al., 1993).

Figure A11-1: Steps for conducting an HRC valuation of I&E losses.



A11-2 Steps in the HRC

A11-2.1 Quantify I&E Losses by Species

The first step in an HRC valuation quantifies the I&E losses from a § 316(b) facility by species. This defines a CWIS's absolute and relative impacts on various species, including temporal variations when multiple years of data are available. The quantified I&E losses by species define the gains of aquatic organisms that restoration actions should achieve. However, EPA's analyses are generally based on data provided by the facility and therefore do not include losses of species not targeted by monitoring programs. In these cases, estimates of potential benefits of regulation will be underestimates. The HRC method partially alleviates this problem because restoring habitats for monitored species is likely to benefit other species lost but not monitored.

Because measured I&E losses often include multiple life stages (e.g., eggs, larvae, juveniles, adults) of any given species, total losses for each species are generally expressed as equivalent losses in a single, common life stage (see Chapter A5). This conversion is accomplished through the use of survival and production rates between life stages (younger life stages are always more abundant than older life stages because of mortality rates). A common life stage is generally chosen to facilitate the scaling of the restoration alternatives. For instance, early life stages are highly relevant for determining how much spawning habitat is required in cases where the productivity of spawning habitats is estimated. Adjusting the raw I&E loss data to a common life stage does not bias HRC results because many eggs are equivalent to fewer adults on both the I&E loss and the restoration gain side of the HRC equation. In other words, losing an adult to I&E is equivalent to losing many eggs because the adult represents survival through many life stages, and restoring an adult is equivalent to restoring many eggs for the same reason. Therefore, the life stage selected for reporting the losses should be chosen to be highly relevant to the life stages affected by (and measurable in) restoration activities. Typically, early life stages such as eggs, larvae, or juveniles are chosen because they tend to be less mobile than adults, and abundance will be better related habitat productivity estimates for replaced habitats.

A11-2.2 Identify Habitat Requirements of I&E Species

The second HRC step identifies the habitat requirements of the aquatic organisms lost to I&E. A species' habitat requirements are usually identified through literature searches and discussions with local resource managers, biologists, conservationists, and restoration experts with specific knowledge of the species.[2] HRC valuation uses local species characteristics and local habitat requirements and opportunities because of variation of local habitat conditions and constraints.

Because many aquatic organisms experience I&E in their earlier life stages (e.g., eggs, larvae, and juveniles), this step emphasizes habitat requirements for these stages, including spawning habitats. This emphasis is important because reducing constraints on adequate spawning is critical to increasing species production, is practical to achieve, and addresses directly the life stages most at risk from impingement and entrainment.

Habitat requirements for a species are typically described in very general terms (e.g., near-shore areas, wetlands, open water areas), but additional characteristics required or preferred by the species (e.g., specific ranges of water depth and temperature, substrate composition) further define the required habitats and improve the match between the habitat requirement and a restoration alternative. For example, a number of species benefit from a general wetland restoration program, but very different species and populations would benefit from a program of prairie pothole restoration compared to the restoration of cattail marshes hydraulically connected to the Great Lakes.

A11-2.3 Identify Potentially Beneficial Habitat Restoration Alternatives

The third step in an HRC valuation identifies actual habitat restoration alternatives that potentially increase the local production of the I&E species. As with identifying habitat requirements, thorough literature searches and discussions with local resource managers will provide optimal information. Special attention should be paid to any remedial action plans for local water bodies or local species management plans that present a series of projects or actions needed to address both specific and general constraints on the populations of aquatic organisms experiencing I&E losses.

Fully addressing I&E costs requires that this step not limit consideration to restoration actions already completed or already planned. Information about projects planned or under way is valuable, but more comprehensive information about what restoration activities improve the production of the affected species sufficient to fully offset I&E losses is essential to understand the full cost to society of I&E losses to the environment and the public. In other words, costs should be constrained only by biological understanding and engineering capability rather than existing funding and administrative opportunities.

The difference between what is being done or planned and what could be done may in some cases be small; in other cases it may be quite significant. For example, there may be little administrative opportunity for local wetland restoration in a location zoned for urbanized development. However, if available information and expert opinion suggest that increasing wetland acreage would be highly effective for increasing local production for a subset of affected species, a wetland restoration program should not be eliminated from consideration even if it could not be implemented locally.

A11-2.4 Consolidate, Categorize, and Prioritize Identified Habitat Restoration Alternatives

The fourth step in an HRC valuation consolidates and categorizes the identified restoration alternatives and provides a prioritized list of alternatives for each species, including designation of a preferred restoration alternative for the species. This step addresses both overlapping restoration alternatives and alternatives that vary widely in specificity. Consolidation and categorization eliminates redundancy in the proposals while producing a clearly defined set of restoration alternatives without prescribing specific actions to be taken.

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[2] Very little may be known about life stage characteristics and needs of some species, and information about taxonomically related species or functionally related life stages may be used. Where relevant information is extremely limited, best professional judgment must be applied, including the possibility of omitting the species from the analysis due to lack of information (and further underestimating benefits).

For example, "restore cattail marshes that are hydraulically connected to Lake Erie" could emerge as a restoration alternative from this process, and "restore the10-acre tract of former wetlands adjacent to marina X" would not be considered because of its specificity. At the other extreme, overly simplified proposals such as "improve water quality" are too general to determine restoration actions with definable costs.

The second part of this step, prioritizing the restoration alternatives, requires identifying a preferred alternative for each I&E species. This identification and prioritization of a preferred alternative is critical for developing a clear restoration program with a hierarchy of actions required to address the losses for a species. Otherwise, because a species may realize varying degrees of increased production from a number of restoration alternatives, an unmanageably large number of combinations of restoration alternatives with varying scales of implementation could be developed.

Prioritizing the categorized restoration alternatives benefits from close coordination with local resource managers. One effective strategy for completing this task convenes relevant resource managers and stakeholders for an open review and discussion of the categorized restoration alternatives with a goal of consensus on the preferred restoration alternative for each species with I&E losses.

A11-2.5 Quantify the Expected Increases in Species Production for the Prioritized Habitat Restoration Alternatives

Quantifying the benefits of the preferred restoration alternatives to I&E species, the fifth HRC step, is critical for scaling the amount of restoration needed to offset calculated I&E losses. Rigorous, peer-reviewed studies that quantify production increases of I&E species which result from particular restoration activities are the best sources of data. These studies measure pre- and post-restoration production in the habitat. Identifying suitable control habitats to substitute for the pre-restoration state is reasonable but less preferred than using pre- and post-measurement from the same site.

Estimates of the potential increases in species production following habitat restoration are more typically based on sampling data from studies that measure the population density of species in various habitats. This estimates increases in species production per unit of restored habitat by assuming that restoration provides similar habitat with similar productivity to that sampled. Estimates of the increased species production following restoration activities should account for lower initial (and perhaps permanent) productivity in restored versus pristine or unimpaired habitats. Estimates of increases in species production should include adjustments for factors that distinguish measured habitats from sites which could be restored (for a discussion of some of the factors that can affect productivity estimates in restored habitats, see Strange et al., 2002). Again, local resource managers are essential to making realistic adjustments. In practice, these adjustments are usually integrated as a percentage of estimated baseline benefits in the HRC equation.

Neither restoration productivity data nor habitat density data are available for some I&E species. For these species, estimates of the increase in species production can come from models of habitat-species relationships such as Habitat Suitability Indices (HSI), data or studies on other habitats or other species with similar functional characteristics, or the best professional judgment of local resource managers.

A11-2.6 Scale the Habitat Restoration Alternatives to Offset I&E Losses

The sixth step scales the selected habitat restoration actions so that the magnitude of their expected increases in species production offsets I&E losses. This step combines the estimated increases in species production associated with the restoration actions (step 5) with the quantified I&E losses (step 1). In the simplest case, one fish species experiences I&E losses in one life stage and wide agreement exists on how implementing the preferred restoration alternative would increase the production of the species for the affected life stage. Dividing the I&E loss by the expected increase in species production associated with a unit area of restoration determines the number of units (and thus the scale) of restoration required (this assumes the I&E losses and the expected increases in species production are expressed in the same time units, e.g., annual average). For example, if a facility's CWIS impinges and entrains 1 million year-one gizzard shad per year and local wetland restorations produce 500 year-one gizzard shad per acre per year (and wetland restorations are recognized as the most effective and cost-effective restoration alternative for gizzard shad), then offsetting these I&E losses requires successful, sustained restoration of 2,000 acres of wetlands.

The typical case involves multiple species with I&E losses across several life stages, variation between species in the expected increases in species production per unit of restoration area, and multiple restoration alternatives to benefit all affected species. In these cases, dividing I&E losses for each species by its expected increases in species production per unit of restoration area still results in the required scale of restoration for each species. However, where a single restoration activity is the primary means to benefit multiple species, enough habitat must be restored to produce all of the species' losses. This means that the species with the lowest per unit production benefit value determines the amount of that restoration required. For example, if 1 million year-one gizzard shad and 1 million year-one emerald shiners are lost to I&E every year, if wetland restoration is the most effective and cost-effective restoration alternative for both species, and if local wetland restorations have been documented to produce 500 gizzard shad per acre per year but only 100 emerald shiners per acre per year, then offsetting the I&E losses of both species requires 10,000 acres (not 2,000 acres) of successful, sustained wetland restoration.

Whether multiple restoration activities will benefit species with disparate habitat needs or whether restoration requirements vary widely among species benefitting from the same restoration activity, production of one species will not offset losses of another species because each species provides unique ecological services through its interactions with other species and has an associated public existence value as a unique species. Therefore, all I&E losses are treated as significant in the HRC method. However, particular species may benefit from activities other than the preferred alternative where multiple restoration activities must address all species, reducing the amount of the preferred alternative required for the particular species. Further, great uncertainty about the amount of a restoration alternative required for many species will require the use of a median, 90th percentile, or other reasonable upper bound likely to offset the I&E losses for most of the species. Here, the risk of underestimating total I&E costs by inadequately restoring some species must be compared to the risk of artificially inflating I&E costs because of uncertainty alone. Using the highest restoration cost to ensure that all species' I&E losses are offset may not be justified, particularly if very few of the species drive the cost orders of magnitude higher. For example, wetland restoration may be the only alternative with cost estimation data and species density data at a site, but the productivity estimates for many species are highly variable and based on limited data or extrapolations.

Both I&E losses and the expected increase in species production associated with a unit area of restoration are expressed as average annual losses for a species at a specific life stage. However, the expected annual average increase in production from a restoration action may be obscured by variability in the flow of benefits, especially in the early years when changes to existing habitats and ecosystem responses are expected to occur. Therefore, a benefits path must describe when and to what extent expected benefits will accrue, and an annual discount rate must be applied (as in the HEA applications described in Peacock, 1999). Benefits of restoration can be expressed in perpetuity, as an annual value, or for a discrete time period.[3]

A11-2.7 Develop Unit Cost Estimates

In the seventh step, an HRC valuation monetizes the unit costs (e.g., costs per acre) for restoration alternatives. Unit cost estimates include all expenses associated with the design, implementation, administration, maintenance, and monitoring of each restoration alternative. These costs include agency oversight costs and all required materials and labor purchased on the open market.

Similar completed projects provide an excellent source of cost information since they reflect real-world experiences. An alternative source of information is the cost estimates from proposed projects not yet implemented or partially completed projects. In either case, factors that can affect per unit restoration costs, such as fixed costs (e.g., administration, permitting) or donated services and materials, should be accounted for by carefully examining the available cost information. The cost analysis of each restoration alternative should also include the costs for an effective program to monitor the increases in species production. Monitoring costs for a restoration alternative should be listed separately, should include all relevant species, and should be of a sufficient length and duration to show the effectiveness of the chosen alternative in different years that capture natural variability. Where costs are not developed on a per unit restored basis, total costs can be divided by the scale of the project to develop the required unit costs. Finally, unit costs are converted to their present value equivalents to simplify addressing costs that may be incurred over a number of years.

A11-2.8 Develop Total Value Estimates for I&E Losses

After the required scale for restoration and the associated unit costs have been determined, the eighth step estimates the total value of all I&E losses. Multiplying the maximum required scale of implementation to offset I&E losses for a species by the unit cost for the restoration alternative produces the costs of a single restoration alternative. The total cost of offsetting the

[3] However, accurate and complete measurement of annual variation of I&E losses is often unavailable, limiting the utility of annualizing HRC.

I&E losses is then equal to the sum of the costs of each restoration alternative implemented, following their prioritization for each species.

The total estimated cost of replacing all of the organisms lost is a discrete, present value representing the current cost for providing a stream of increased production benefits for the affected species in perpetuity. In other words, the HRC valuation estimate reflects the cost now for increasing the production of I&E species at an average annual level that would offset the losses in the current year and all future years, all else being equal.

A11-3 Use of the HRC Method for § 316(b) Evaluations

EPA Region 1 is currently applying the HRC method at the Pilgrim Nuclear Power Generating Station in Plymouth, Massachusetts, and the Brayton Point Station in Somerset, Massachusetts. In addition, EPA applied a streamlined HRC valuation for the benefits case studies of the J.R. Whiting facility on Lake Erie and the Monroe facility on the River Raisin, a tributary to Lake Erie, to test the applicability of the method under time and budget constraints often faced by NPDES permit writers (see Parts H and I of this document).

A11-4 Strengths and Weakness of the HRC Method

The primary strength of the HRC method is the explicit recognition that I&E losses have impacts on the aquatic ecosystem and the public's use and enjoyment of that ecosystem beyond that estimated by reduced commercial and recreational catches. The HRC method provides a supplemental or alternative option for determining the value of I&E losses of all species, including forage species overlooked by conventional methods, so that the public (i.e., those directly and indirectly affected by I&E) and the regulators who represent them can have greater confidence in the true range of values associated with I&E losses. The need for detailed restoration alternatives for the HRC method provides permitting agencies with a way to scale the mitigation level to offset residual I&E losses associated with a permitted technology. Finally, the HRC method has a strong intuitive appeal as a valuation tool because it uses the costs associated with enhancing natural habitats so that they will produce the equivalent number and type of resources necessary to offset the I&E losses produced by the CWIS.

Public confidence in HRC valuations will be determined by the quality of input data for identifying preferred restoration alternatives, estimating increased production following restorations, estimating complete unit costs for restorations, and monitoring the relative success of restoration efforts. In this sense the HRC method does not have a methodological weakness. However, failure to identify all species lost to I&E, lack of information about life histories and habitat needs for some species lost, and abundance data poorly linked to restored habitat productivity are likely to continue to force cost-saving assumptions that undervalue the total benefits of minimizing I&E.

EPA's studies are limited by the quality and extent of the I&E data collected by the facility. This weakness can be addressed in future analyses by using appropriate guidelines for monitoring I&E, and by planning a more active program of defining expected production increases for species following implementation of different restoration activities. In practice, implementing appropriate monitoring programs for both the harm done by a CWIS and the benefits gained from restoration projects will produce a more comprehensive database. This comprehensive database will then facilitate scaling restoration projects to replace I&E losses. By ensuring that the costs associated with such monitoring programs are incorporated in the unit costs used to value I&E losses, the HRC method will help develop the information needed to address this limitation.